Geological Society of Malaysia Annual Geological Conference 2001
June 2–3 2001, Pangkor Island, Perak Darul Ridzuan, Malaysia

Occurrence, field relations and petrochemistry of mafic dykes from the Kenyir area, central Terengganu: Preliminary observation

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Abstract: The Kenyir lake is located in the western side of the Terengganu state, about 17 km from Kuala Berang, the nearest township. This paper will focus on the mafic dykes that occur at the eastern part of the Kenyir lake area. Intrusion of the mafic dykes in the study area are apparently controlled by a pre-existing NE-E trending fracture. The trend is similar to the regional mafic dykes trend in the Eastern Belt. The silica content of the dykes are between 48.8 to 58.8% and can be classified as basalt-basaltic andesite and basaltic trachyandesite on a TAS diagram. The chemical data indicate that the dykes are tholeiitic, and formed in a continental within plate tectonic setting.

Abstrak: Tasik Kenyir terletak dibahagian barat negeri Terengganu, lebih kurang 17 km dari bandar terdekat, Kuala Berang. Kertas ini akan membincangkan kewujudan daik mafik yang dijumpai di bahagian timur Tasik Kenyir. Penerobosan daik mafik di kawasan kajian dikawal oleh retakan berarah timurlaut-timur yang telah sedia wujud. Tren ini adalah sama dengan tren daik mafik rantau di kawasan Jalur Timur. Kandungan silika daik-daik ini ialah antara 48.8 hingga 58.8% dan dalam gambarajah TAS mereka boleh dikelaskan sebagai andesit dan basaltik trakiandesit. Data geokimia menunjukkan daik-daik ini adalah toleitik dan terbentuk di sekitaran tektonik dalam plata pada sekitaran benua.

INTRODUCTION

Mafic dykes intruding both intermediate to felsic igneous rocks and older layered rocks, are found widespread, not only in the mainland but also in several islands off the east coast of Peninsular Malaysia (Yaw 1977; Kumar 1977; Haile *et al.* 1983; Azman 1992; Azman *et al.* 1998). The older dykes occur synplutonically with their host rock whereas the younger dykes, which are more abundant, postdates the host rock. In this paper we report field and petrochemical data of an ongoing research on the mafic dykes from the Eastern Belt of Peninsular Malaysia. This paper will focus on the mafic dykes that occur at the eastern part of the Kenyir lake area, central Terengganu (Fig 1). The dykes are extensively exposed in this area because of the dam construction mainly in the mid-80's and construction of the Kenyir-Lojing-Simpang Pulai highway. Field data, sketches and maps presented in this paper are a summary from unpublished work (BSc thesis, Department of Geology, University of Malaya ; Wan Zakaria Wan Ibrahim 1982; Rekman A. Rashid 1994; Afandi Muda 1993; Wan Salmi Wan Harun, 1997) and unpublished data of the first author. We are fortunate to have a detail dyke map of the Kenyir damsite (Empangan Sultan Mahmud in Jenagor area) during the construction in 1982 by Wan Zakaria Wan Ibrahim. Recently the construction of the Kenyir-Loging-Simpang Pulai highway exposed more mafic dykes. However much of the outcrop in the highway construction have been covered by shortcrete which obliterate much of the detail that was visible. It is felt that the details of this dykes exposure should be made available to other geologists who cannot observe them now due to the weathering of the exposures.

GENERAL GEOLOGY AND FIELD OCCURRENCE OF THE DYKES

The Kenyir lake is located in the western side of the Terengganu state, about 17 km from Kuala Berang, the nearest township. Much of the geology of the study area was described by MacDonald (1967) in the Geology and Mineral Resources of North Kelantan and Terengganu areas and by Hutchison (1973). Generally the catchment area is underlain by felsic igneous rock mainly of granite and granodiorite, marine clastics (shale and sandstone), minor carbonates with some metamorphics (phyllite, quartzite) and basic to intermediate volcanics. The eastern part of the Kenyir Lake, however is underlain by granitic rocks of the Kapal batholith. The batholith is a composite body ranging from diorite to monzogranite in composition and is dominated by granodiorite. The granites in both areas have been intruded by dykes of mafic to intermediate composition with average thickness ranging from 10 cm to 50 meters. The thicker dykes commonly show chilled margins and a regular inward increase of grain size. They are almost planar and near vertical, but some may have dip as low as 45°. Detailed dyke map of the Kenyir damsite is shown in Figure 2. The map shows that the dykes do not appear continuous over long distances but are *en-echelon* in character, pinching out and re-appearing again and

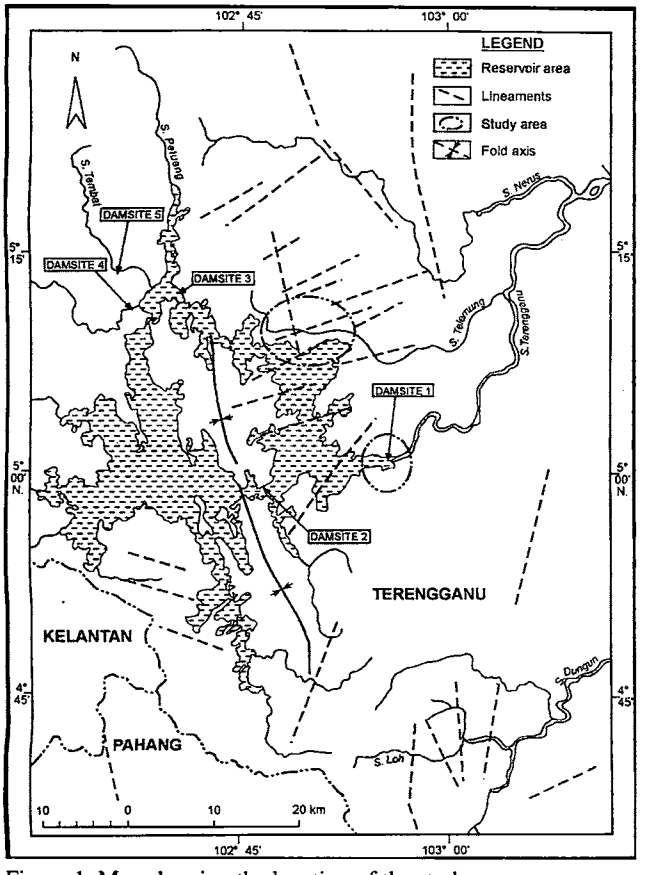

Figure 1. Map showing the location of the study area.

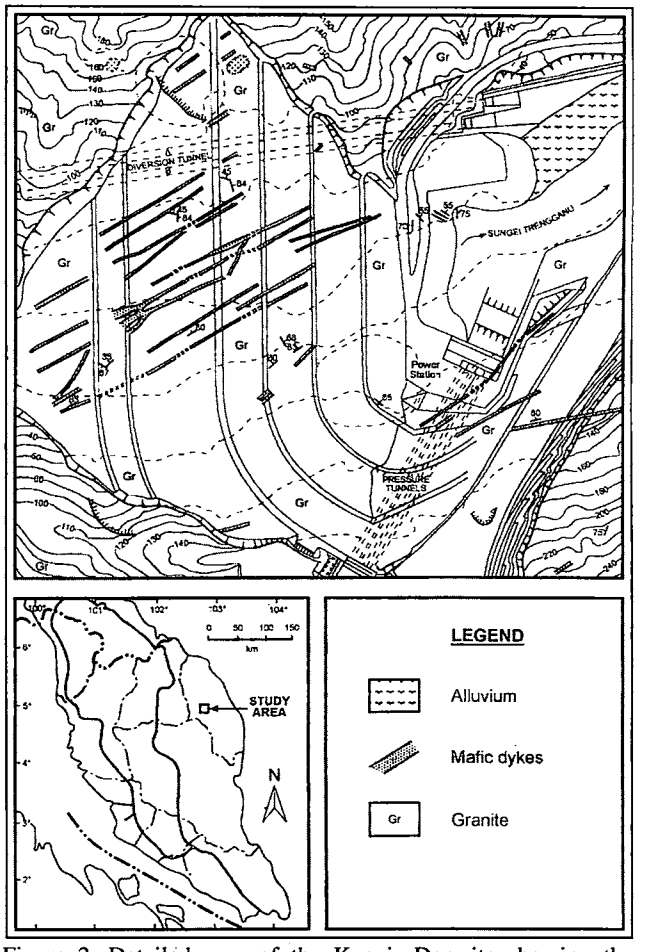

Figure 2. Detailed map of the Kenyir Damsite showing the distribution of the mafic dykes during the construction work (mid 80's) (Map by Wan Zakaria Wan Ibrahim, 1982).

sometimes slightly displaced from their original trend. Sketch of some dykes in a selected damsite wall are shown in Figures 3 and 4 (Wan Zakaria Wan Ibrahim, 1982). In the Kenyir-Loging-Simpang Pulai new highway, a total of 6 dykes are found intruding the granitic rocks along the first 9 km of the highway. The whole area is covered by granite with some metasediments at km 7, probably as a roof pendant.

Majority of the dykes strike between NE to E, with an exception of three dykes recorded by Wan Zakaria Wan Ibrahim (1982) at the Kenyir Damsite which show N-S strike. Wan Zakaria Wan Ibrahim (1982) also noticed that the dykes from the Kenyir Damsite follow the trend of the joints. General strike trend of the mafic dykes from the study area is similar to the recorded strike direction of mafic dykes from Kuantan (Haile *et al.*, 1983) and Perhentian (Azman, 1992) areas.

PETROGRAPHY

MacDonald (1967) reported two groups of dykes occuring extensively in the study area, they are dolerite which is dominated by plagioclase and clinopyroxene and lamprophyre group which is dominated by amphibole. However in the present study majority of the dykes are dolerite. The dyke rocks are made up of plagioclase, clinopyroxene, amphibole, iron ore and chlorite. In general, the texture is either intergranular or subophitic. The rocks are often chloritised to varying degrees and in the most extreme case up to about 20% modal chlorite was observed. Pale green fibrous uralite may be present within the chlorite. MacDonald (1967) suggested that both chlorite and uralite are late magmatic phases. Plagioclase crystals occur as small subhedral to euhedral laths which do not show any preferred orientation. Wan Zakaria Wan Ibrahim (1982) recorded the plagioclase composition of the dykes from the Kenyir damsite is mainly andesine (An_{32} - An_{35}, 2V = 84 - 88). The crystals sometimes show twinning but rarely zoning. Clinopyroxene, mainly augite, generally subhedral to anhedral occurs as interstitial grains between plagioclase laths forming a typical doleritic texture. In some samples, euhedral to anhedral iron ore can constitute up to 10 %. MacDonald (1967) showed that ilmenite is the main iron ore type in the quartz dolerite from the Eastern Belt. In rare cases, some interstitial calcite may occur. Quartz occurs as interstitial mineral with minute fluid inclusions.

GEOCHEMISTRY

Six dykes and three host granite samples from the study area were analysed for major and trace elements compositions. All samples were analyzed by x-ray

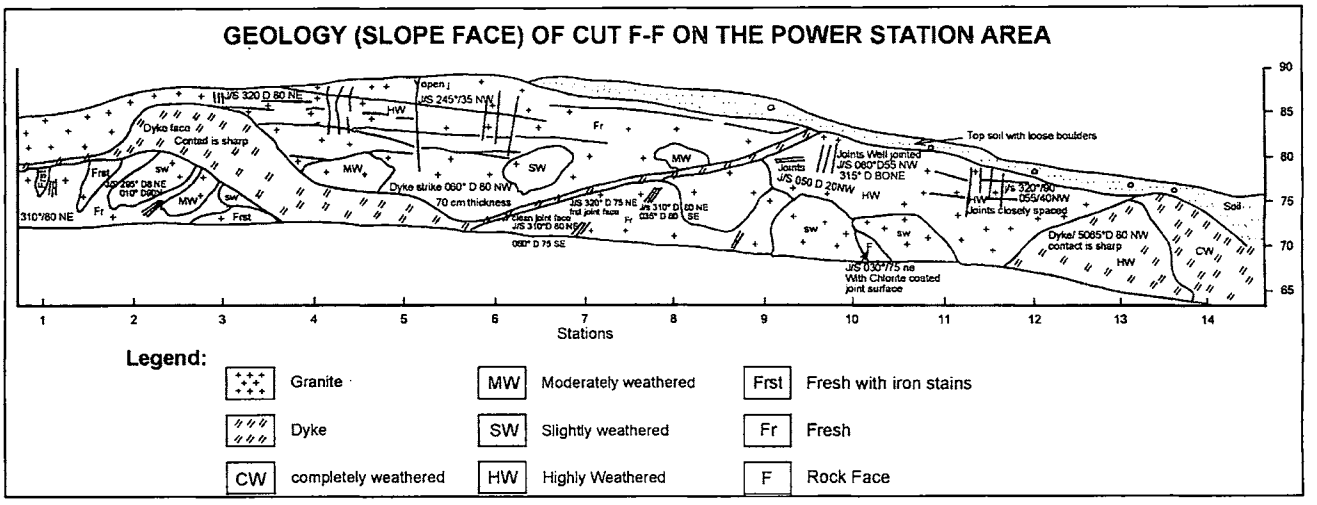

Figure 3. Field sketch of one (F-F') of the slope face on the power station area showing field relation of mafic dykes (Wan Zakaria Wan Ibrahim 1982).

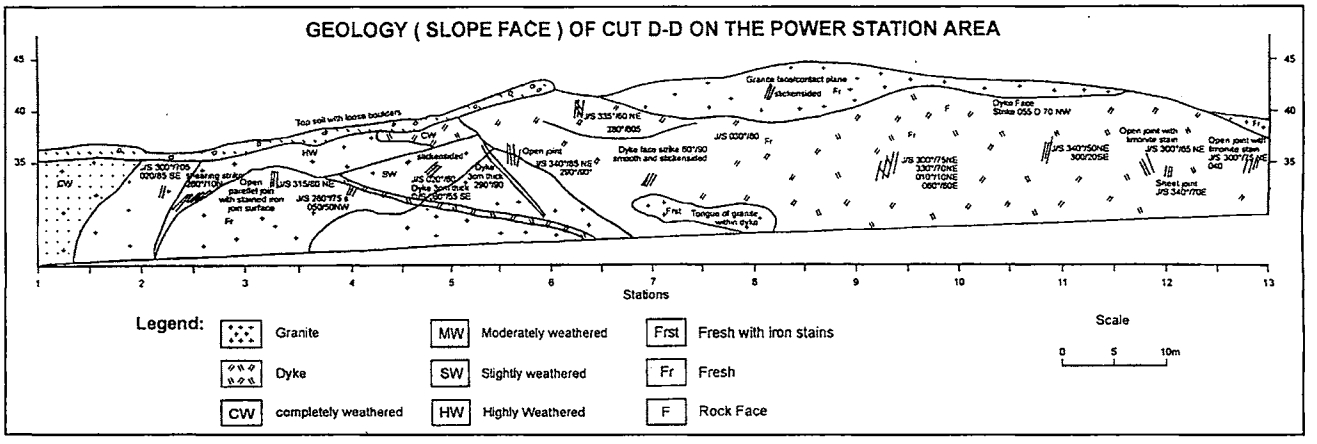

Figure 4. Field sketch of one (D-D') of the slope face on the power station area showing field relation of mafic dykes (Wan Zakaria Wan Ibrahim, 1982).

fluorescence (Phillips PW 1480) at University Kebangsaan Malaysia (trace elements) and Mineral and Geoscience Department (major elements), Ipoh. In addition to the above analyses, eighteen analyses mainly of major elements were obtained from unpublished theses of the other authors of this paper (Wan Zakaria Wan Ibrahim, 1982; Rekman A. Rashid, 1994; Wan Salmi Wan Harun, 1997). Representative analysis of the major and trace elements of the mafic dykes in the study area is given in Table 1. Also included in Table 1 is the average for continental tholeiites an ocean floor tholeiites (Pearce, 1975; Roberts *et al.*, 1991).

The silica content of the dykes are between 48.8 to 58.8 wt%. Comparing the elements abundant with reported average values for continental tholeiites and ocean floor basalt (Table 1), it is clear that the dyke is more akin to continental tholeiites than to basalt generated in an ocean floor setting. Both continental tholeiites and ocean floor basalt show a significant difference in TiO_2 (2.47 and 1.43 wt% respectively), Al_2O_3 (14.41 and 16.20 wt% respectively) and MgO (5.96 and 7.74 wt% respectively) content. Of the three elements the Kenyir dykes have similar Al_2O_3 (mean: 14.6 wt%) and MgO (mean: 5.14 wt%) content to the continental tholeiites. The studied dykes, however have low Fe^{tot} and CaO and high Na_2O and K_2O compared to both continental tholeiites and ocean floor basalt. On a total alkali silica (TAS) diagram (Le Maitre *et al.*, 1989) (Fig. 5) majority of the samples plot in the basalt-basaltic andesite and basaltic trachyandesite fields. Also shown in the diagram is a subdivision line (alkaline and tholeiite fields) of volcanics rocks by Irvine and Baragar (1971) and only five out of twenty samples plot in the alkaline field, others plot in the tholeiite field. On a TiO_2 vs K_2O vs P_2O_5 plot (Pearce *et al.*, 1975), all the samples plot in the continental fields (Fig 6). On Ti/100-Zr-Yx3 ternary diagram (Fig 7), all samples plot on the within plate basalt field. Hence, the chemical data indicate that these dykes are tholeiite and formed in a continental within plate tectonic setting.

The magmatic affinities and tectonic setting of the presently studied dykes is similar to the dolerites from the Kuantan area (central Eastern Belt) which also range in composition from olivine tholeiite to quartz tholeiite and bear affinities to the tholeiites of continental setting (Chakraborty, unpublished work, in Sita Ram *et al.*, 1980). Regionally, the tectonic setting of the dykes are similar to the Upper Paleozoic volcanic rocks from Chiang Mai belt,

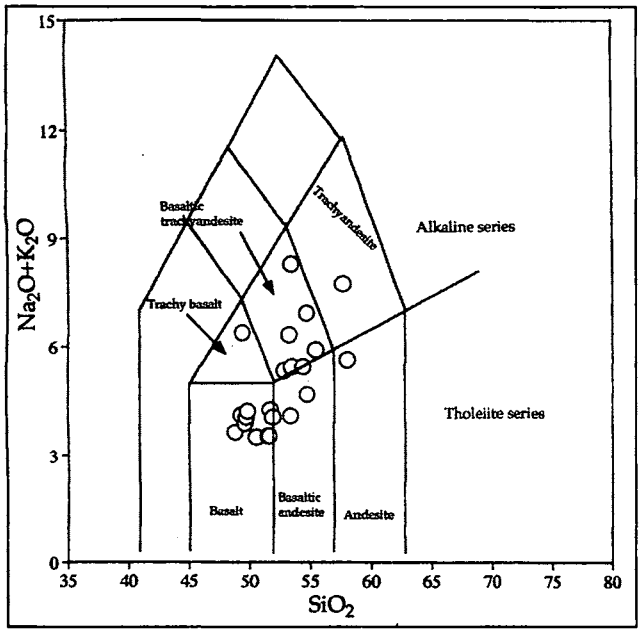

Figure 5. TAS diagram of the mafic dykes from the Kenyir area.

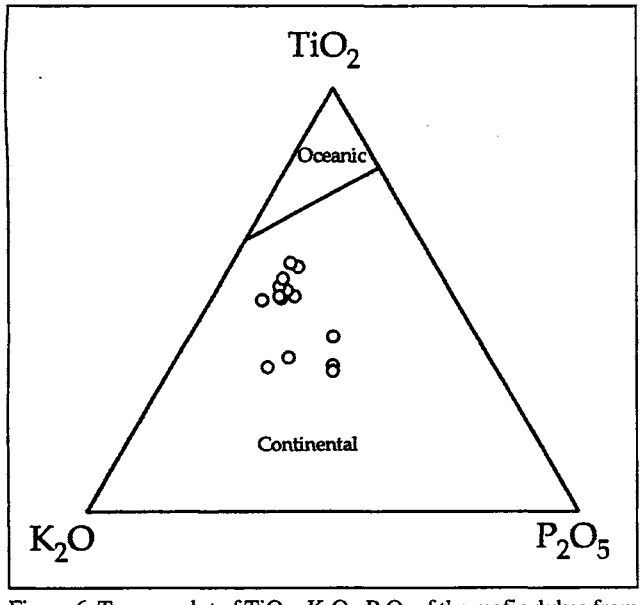

Figure 6. Ternary plot of TiO_2 - K_2O - P_2O_5 of the mafic dykes from the Kenyir area.

northern Thailand (Barr *et al.*,1990) and Upper Cenozoic basaltic rocks of Thailand, Kampuchea and Vietnam (Barr and James, 1990).

CONCLUDING REMARKS

Intrusion of the mafic dykes in the eastern part of the Kenyir lake have apparently been controlled by a pre-existing NE-E trending fracture. The trend is similar to the regional mafic dykes trend in the Eastern Belt. The dyke rocks can be classified as basalt-basaltic andesite and basaltic trachyandesite. The chemical data indicate that the dolerites are of tholeiitic, and formed in a continental within plate tectonic setting.

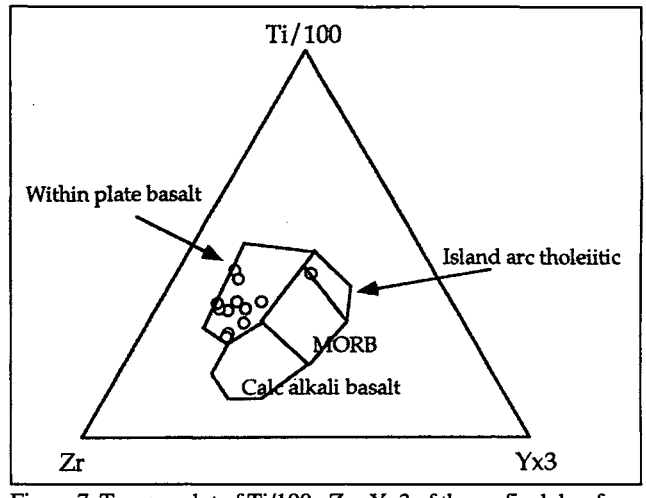

Figure 7. Ternary plot of Ti/100 - Zr - Yx3 of the mafic dykes from the Kenyir area. Fields from Pearce and Cann (1973).

ACKNOWLEDGEMENTS

Encik Ching Yu Hay and Encik Azrai are thanked for drafting the maps. Thanks also due to Prof. Hamzah Mohamad from Program Geology, UKM for XRF works. AAG acknowledges the research grant received from University Malaya (Vot F 0537/1999B).

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Table 1. Representative major and trace element compositions of the mafic dykes from the Kenyir area, together with mean for continental tholeiites (CON) and ocean floor tholeiites (OFB).

Sample	S12	S15	S5	S7	CON	OFB
wt%						
SiO_2	53.29	49.46	53.45	53.46	48.81	49.91
TiO_2	1.68	1.74	1.73	1.67	2.47	1.43
Al_2O_3	13.05	15.55	13.80	13.84	14.41	16.20
Fe_2O_3	13.87	10.82	12.48	12.84	13.20	10.24
MnO	0.25	0.19	0.30	0.31		
MgO	2.59	6.33	3.16	3.02	5.96	7.74
CaO	6.64	7.63	6.20	6.40	10.05	11.42
Na_2O	4.00	5.10	3.32	5.52	2.90	2.82
K_2O	2.28	1.27	1.92	1.89	0.95	0.24
P_2O_5	0.97	0.79	1.05	1.05		
LOI	2.26	2.77	1.50	1.44		
Total	100.88	101.65	98.91	101.44		
ppm						
Ba	857	678	1561	1373	338	8
Ce	98	75	187	161		
Co	54	23	46	39		
Nd	95	11	55	19		
Ni	bdl	60	2	2	68	106
Pb	bdl	bdl	bdl	bdl		
Rb	57	42	49	47	15	3
Sr	245	380	330	300	401	131
Y	52	28	42	41	25	30
Zr	752	236	351	349	149	92

Fe_2O_3 : Total Fe given as Fe_2O_3
CON : Mean for Continental Tholeiites
OFB : Mean for ocean-floor tholeiites
bdl : below detection limit

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